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CONCEPTUAL REVIEW AND THE PRODUCTION, CONSUMPTION AND PRICE MODELS OF THE NATURAL RUBBER INDUSTRY IN SELECTED ASEAN COUNTRIES AND WORLD MARKET

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ABSTRACT

Natural rubber (NR) is one of the crucial commodities in the world and also extensively used in many applications and products. The objectives of the study are to develop the conceptual review and to analyze the production, consumption and price models of the NR in selected ASEAN countries and world market. The production model is the function of the NR price for five selected ASEAN countries such as Thailand, Indonesia, Malaysia, Vietnam and Myanmar. The consumption model is the function of the domestic NR price and domestic stock of the four largest rubber consuming countries which are China, India Japan and USA. The world NR price model (Singapore SICOM price) involves the factors such as NR production, NR consumption, real exchange rate, and crude oil price. Panel data analysis was performed for the NR production and consumption models by using annual data from year 1997 to 2017; and Vector Error Correction Method (VECM), cointegration test and Granger Causality test were analyzed on the world NR price model using monthly data from January 2008 to December 2017. Lastly, a contribution of this study would be the interest of policymakers for policy implication of the businesses and manufacturing industries that are closely related to rubber.

Contribution/ Originality: This study is one of very few studies which have investigated the natural rubber production and consumption models by using Panel Data Analysis which includes five major producers and four major consumers together with SICOM price model (latest data from International Rubber Study Group) of natural rubber industry in the world market.

1. INTRODUCTION

NR basically is made from a gooey and milky white liquid (Sundaram, 2010) which is known as latex that is obtained from certain plants, and there is almost 99 percent of the world's NR is produced from the latex from a particular species of rubber tree, or as known as *Hevea Brasiliensis* (Woodford, 2017). Latex is in sticky form and extracted by a process called "tapping" into a long cut made from rubber tree then collects the white liquid latex contents (Chanchaichujit and Saavedra-Rosas, 2018). Rubber trees have an economic life period of about 32 years in plantations which require well-drained and well-weathered soils. Other requirements for better result of the growth of the *Hevea* rubber trees include a temperature range between 20°C - 34°C, at least 100 rainy days annually, 80 percent of humidity and 2000 hours of sunshine. Thus, it makes the rubber trees are cultivated widely especially in Southeast Asia Countries which consist of the optimal conditions for rubber trees cultivation, and among the largest NR producers include Thailand, Indonesia, Malaysia, Vietnam and Myanmar (Chen *et al.*, 2016).

Hevea Brasiliensis was originally from Brazil (Priyadarshan and Clément-Demange, 2004) and was then introduced and distributed to Southeast Asia Countries such as Malaysia, Indonesia, Thailand and others during the late 19th century (Khin and Thambiah, 2014). There are two types of rubber which are natural and synthetic rubber (SR). As mentioned, NR is produced from the latex which derived naturally from rubber trees, while the SR is manufactured from chemicals sourced from petroleum refining (IRSG, 2017). SR is also identified as the substitute product of NR and also having an impact on the NR market economically, the consumption behavior of consumers between these two types of rubbers definitely impacts the price and growth of the markets itself. NR is being used in various sectors and industries due to its useful physical and chemical characteristics, such as tire manufacturer, household products and medical devices (Herath *et al.*, 2012). Its flexibility and elasticity make itself become an important commodity in the agricultural sector that can be used in a lot of products.

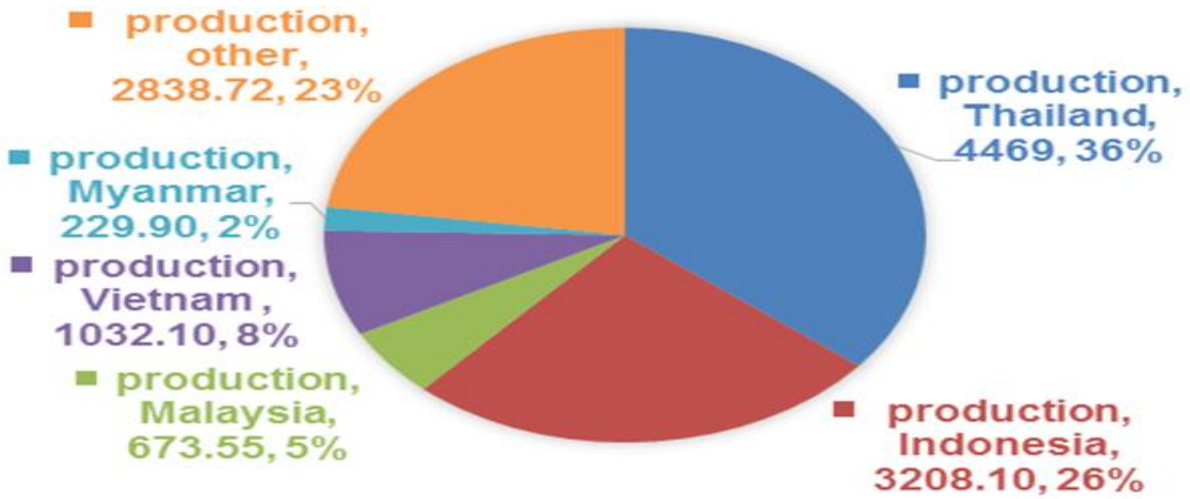

Figure-1. World NR Production as of 2016

Source: IRSG (2017)

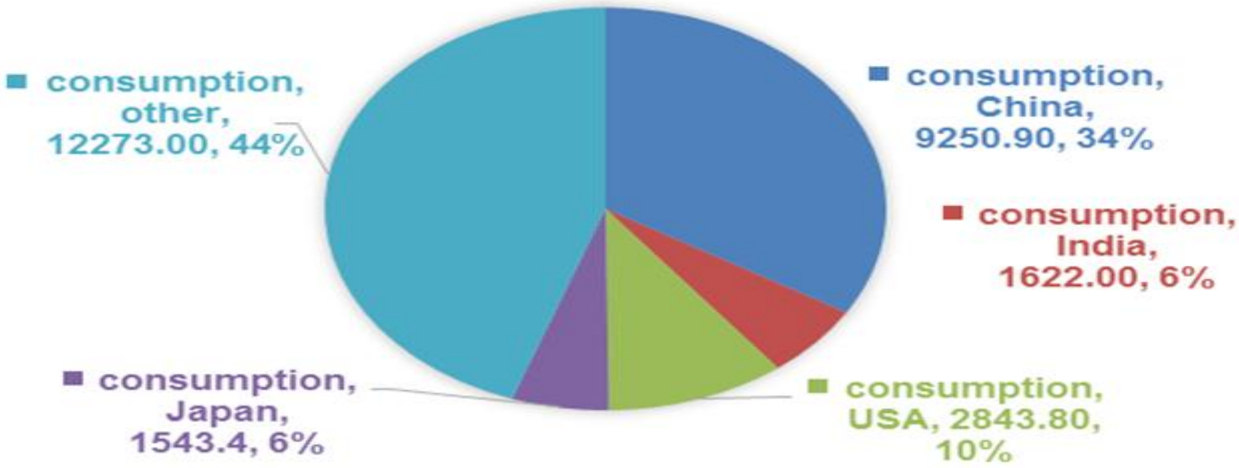

Figure-2. World NR Consumption as of 2016

Source: IRSG (2017)

Figure 1 reveals the world NR production while figure 2 reveals the world NR consumption as of 2016. According to International Rubber Study Group (IRSG), the top five NR producing countries are Thailand, Indonesia, Malaysia, Vietnam and Myanmar; while the top four NR consuming countries are China, India, USA and Japan. According to the statistics from the Association of Natural Rubber Producing Countries (ANRPC, 2017) the NR world production increased from 12.43 million tonnes in 2016 to 13.28 million tonnes in 2017. There was approximately 90% of the world NR supply is produced by ANRPC member countries especially produces from the top five NR producers namely Thailand, Indonesia, Malaysia, Vietnam and Myanmar due to the optimal conditions for the growth of rubber trees. Also, about 70% of the global demand for NR derived from the top four NR consumers namely China, India, USA and Japan mostly for the automobile and auto-tire industries. On the other hand, for the world NR consumption, it showed an increase of 1.4% and the total of 12.9 million tonnes as of year 2017.

According to GRM (2018) Malaysia rubber market was expected to have higher trade and increase in demand in early 2018 which is due to the rise in global oil price as well as the good weather in major producing countries recently. As we all know, Thailand, Indonesia and Malaysia have always been the major producer and exporter in the world NR market for many years. However, Vietnam's NR market was also showing improvements as its export volume in 2017 increased greatly, and it even reached a new peak of the past ten years in August 2017 (GRM, 2018). Besides, after lagging for years behind the world's three main rubber producers, Myanmar's NR production was also showing an upward trend due to the rising international consumption and demand. China is the largest NR consumption country in the world, driven by the steady development of the tire industry. Besides, China's NR consumption was also expected to hit 5.8 million tonnes by 2021, of which 90% of it would be used in radial tires. In fact, about 80% of Myanmar rubber export volume and about 50% of Vietnam's rubber export volume were exported to China, and the proportion was expected to be higher as China's demand is increasing (GRM, 2018).

NR world total production and consumption was increasing steadily ever since the 1990s. This could be explained by the increase in the world technology since the 1990s especially in automobile industries which required tonnes of rubber for the production of automobile tires. According to Sethunath (2016), NR price behaves like all other commodities prices which is bound to occur a periodic boom, or as known as commodity cycle. In fact, the trend also showed that the NR periodic boom had already started to happen since 2004-05. NR price dropped dramatically during the period of 2008-09, which was due to the spill-over effect from the global financial crisis that impacted a lot of smallholders especially in Southeast Asia (Khin and Thambiah, 2014). The NR price bounced back and reached its peak in the year 2011 which was about 3196 USD/ton and followed by a decreasing trend until the end of 2012. This significant rise in NR price was due to low yield in producing countries like Thailand, Malaysia and Indonesia which had experienced heavy rain because of the La Nina phenomenon (Bureau, 2010). Conversely, some China's major rubber producing provinces like Yunnan faced severe drought which also affected the production crucially.

This had a significant impact on the tire industry too. 80 percent of the tire is made up from NR and the material itself already accounts for almost 50 percent of the total unit cost. Due to the phenomena mentioned above, the production of NR had been decreasing. Drop in rubber production had pushed up the price to its peak during 2010-11, which influenced the tire industry to raise the export prices as well. The supply-demand situation had made the rubber market itself become unstable.

Rubber has been playing a key role in the socioeconomics aspect in many of the producing countries which are also developing countries. There are even over 20 million families actually dependent on the production and farming of rubber for their basic sources for the living. However, the volatility of NR price had been affecting their livelihood especially smallholders. Falling rubber price and production caused the farmers and smallholders of rubber to stop tapping due to low income. For instance, in 2016, Malaysia had been hit by a drop of almost 70% in the NR price (Naidu, 2016). It was said by rubber tappers that the rubber price was falling too much too low for them to continue tapping for their living. Thus, the instability of NR price became the motivation of the study, to determine the factors affecting NR production, consumption and the price models in selected ASEAN countries and the world market.

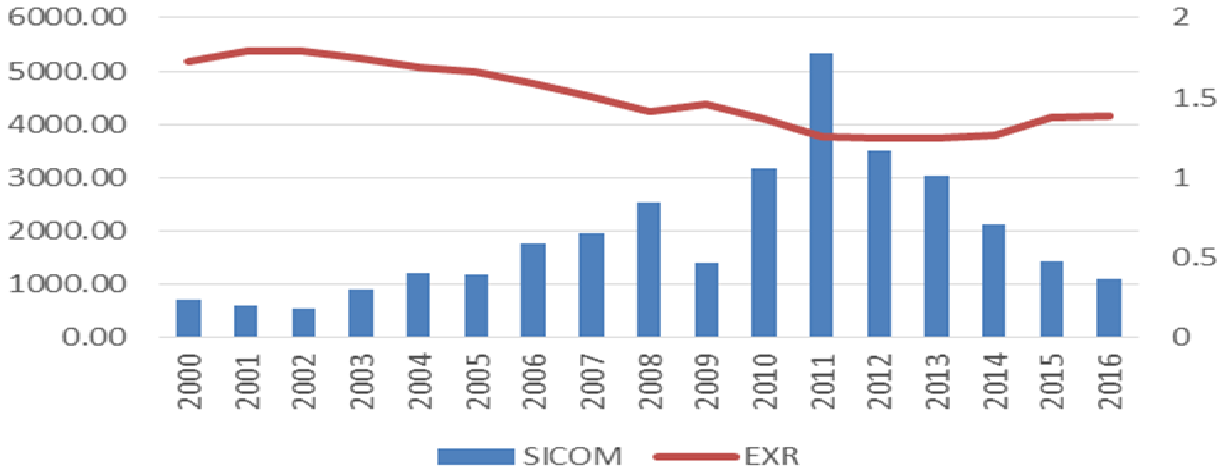

Figure-3. World NR Price (SICOM) USD/ton and Exchange Rate (EXR) USD/SGD

Source: ANRPC (2017)

Figure-4. World NR Price (SICOM) USD/ton and Crude Oil Price (COP) USD/barrel

Source: ANRPC (2017)

There are multiple factors interacting with the NR price around the globe and different studies had been done to investigate the relationship between NR price and the affecting factors. As shown in figure 3, SICOM and EXR behave oppositely, which means that they are having a negative relationship. Fluctuation of NR price could be explained by the volatility of the currency exchange rate since most of the agricultural commodities are traded in US dollar (Khin *et al.*, 2016). The study was conducted to find out that the exchange rate volatility impact on the NR price (both RSS4 and SMR20), using monthly data from January 1990 to December 2015. Results showed that long-run relationship between SMR20 rubber price, RSS4 rubber price, and the exchange rate existed, which was supported by Soares *et al.* (2013) who suggested NR price was affected by the variation in exchange rate. There was also a unidirectional causality relationship between RSS4 and SMR20 price, which RSS4 granger caused SMR20.

Moreover, SICOM and COP are having a positive relationship, as shown in figure 4. Rafiq and Bloch (2016) conducted a research to examine the relationship and linkages between oil price and 25 other different commodity prices such as cocoa, wheat, maize and also including rubber. Nonlinear ARDL cointegration approach (NARDL) was used to capture both short and long run asymmetries in the variables. Results found out that relationship between crude oil and most of the other commodity prices existed, as well as long-run positive effects of oil price on 20 commodities and short-run negative effects for 13 commodity prices. Based on the study, there were a short run and long run linkages between oil price and rubber price, and both of these prices were also correlated. Besides, this study was supported by the recent research by Gupta *et al.* (2015) which also studied the linkages between oil price and other commodity prices using time-varying causality test. Test results showed that there was a bi-directional causality relationship found between oil and rubber price as well.

2. LITERATURE REVIEWS

NR industry has been playing a significant role especially in Southeast Asia countries such as Thailand, Malaysia, Indonesia, Vietnam, and Myanmar. For these countries, as the leading NR producers around the globe, NR production is a crucial factor to the export and import as well as price of rubber. MdLudin *et al.* (2016) employed annual data from 1980 to 2012 and Two Stage Least Square (2SLS) method to conduct an econometric analysis of NR market in Malaysia to find out the main reasons that affecting NR industry in Malaysia. Results showed that there were a few variables affecting the production of NR which were time trend, palm oil price, hectare NR and government expenditure. Moreover, for domestic price equation, there were another two significant factors influencing domestic price which were the world price of NR and the domestic stock; while for the world price model, lagged world price of NR and the crude oil price were the important factors.

Thailand is one of the main producers of NR, leading the world export and production of rubber followed by Indonesia and Malaysia. As a market leader in the rubber industry, it is significant to know that the determinants of NR production, therefore, Chawananon (2014) had investigated the dynamics of the demand and supply of rubber and analyzed the factors affecting the rubber market. Annual data from 1977 to 2012 and Two Stage Least Squares method were used for the analysis. The study found out that U.S. GDP per capita, rainfall (Mesike and Esekhade, 2014; Arunwarakorn *et al.*, 2017) the price of rice as well as the expected rubber price were affecting the rubber production in Thailand rubber market. The relationship between the estimated price and the rubber production existed, and it was also supported by Mesike *et al.* (2010).

Arunwarakorn *et al.* (2017) had conducted a research to study the NR in the world market. Three stage Least Square technique and monthly data from 2004 to 2015 were used. There were two models developed in this research which were demand model and supply model with the objectives to predict rubber production, variables affecting both the models, as well as to estimate the quantity and price of NR in the world market. Results revealed that from the demand model, there was a negative relationship between consumption and price of NR. It was also found that production of NR positively affected the NR consumption. This could be explained as increased in rubber production led to a decrease in rubber price, which will stimulate the demand of NR to rise. Besides, since SR is the substitute product of NR, so when the price of SR rose, consumer started to change their consumption behavior to consume more NR, thus demand for NR increased as well. It showed that SR price and NR demand were positively related.

NR price fluctuations had been one of the factors of economic downturn especially in the rubber-producing country such as Malaysia, thus it was crucial to understanding the factors behind the volatility of rubber price and the forecasting of rubber price too. Therefore, Khin and Thambiah (2015) conducted a study to forecast the NR price using simultaneous supply-demand and price model equation as well as the VECM model. The time trend of the analysis was from Q1 1990 to Q4 2013. Results of the simultaneous supply-demand and price equation revealed that production, consumption and the RSS1 price were the important variables and relationship between these variables and the rubber price existed. It showed that NR consumption had a negative relationship with rubber price. On the other hand, results from the cointegration equation indicated that there was a long-run relationship between NR price and rubber production and consumption, RSS1 price as well as the exchange rate. For the VECM equation, it showed that there was a short-run relationship between the price of NR with only production and consumption of rubber, stock and also exchange rate. Therefore, the objective of the study is to develop the dynamic models for the NR production, consumption and price competitiveness in selected ASEAN countries and world market. Figure 4 illustrates the conceptual framework of the NR production, consumption and price competitiveness in selected ASEAN countries and world market.

3. RESEARCH METHODOLOGY

3.1. Conceptual Framework

The framework shows that there are three models in this study which are (1) the production model that includes five selected ASEAN countries which are Thailand, Indonesia, Malaysia, Vietnam, and Myanmar; (2) the consumption model that includes four largest rubber consuming countries which are China, India USA and Japan; and (3) world NR price model (Singapore SICOM price) includes the factors such as production, consumption, real exchange rate, and crude oil price. Model (1) refers to the NR production and its factor which is the export price of the five producing countries; model (2) refers to the NR consumption and its factors, namely the individual country domestic price and the domestic stock in the four consuming countries. Model (3) refers to the world NR price and the factors influencing it. In the figure, it shows that model (1) and (2) link to model (3), which the production and consumption of NR are two of the factors of NR price.

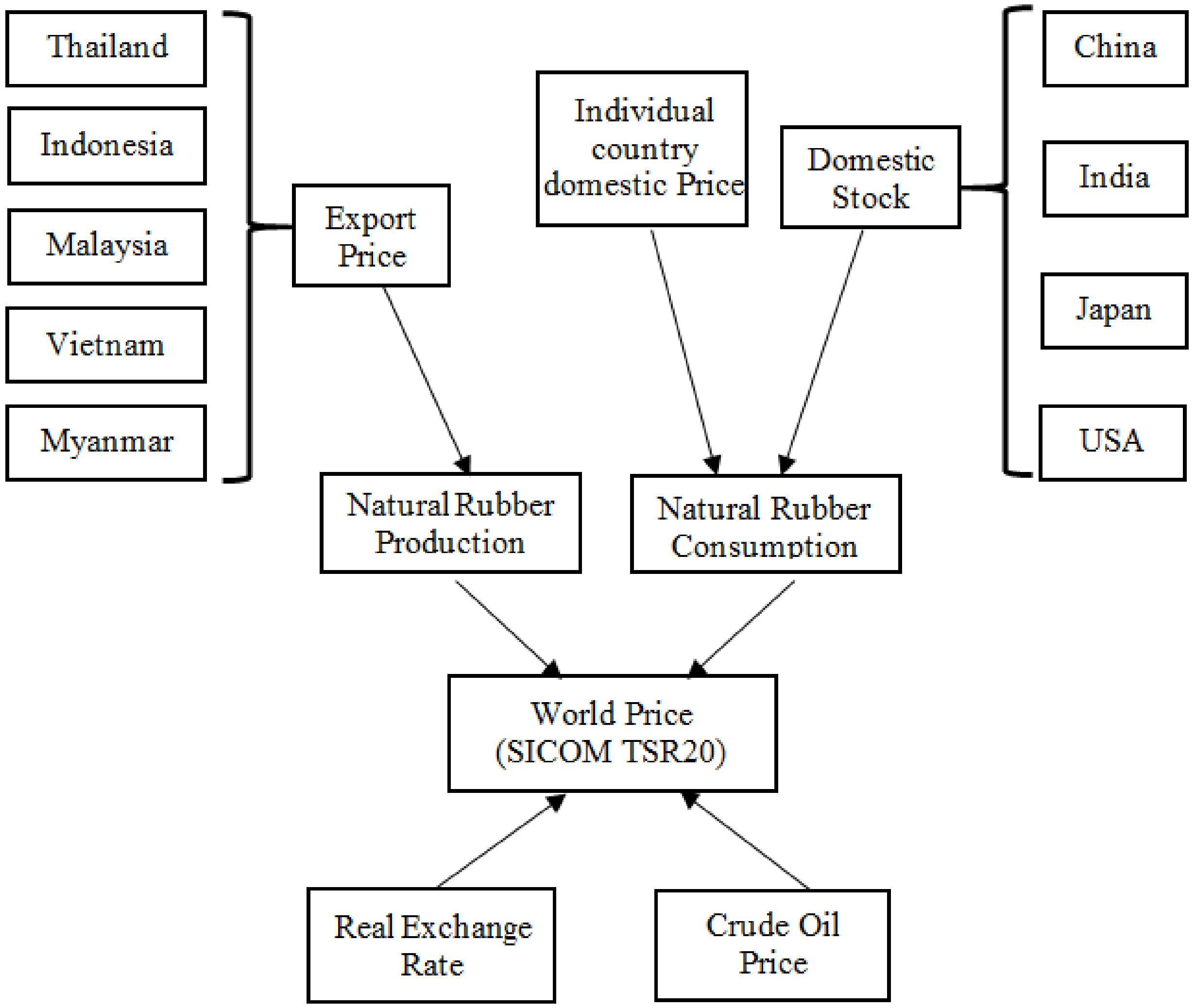

Figure-5. Conceptual Framework of the Production, Consumption and Price Models of the Natural Rubber Industry in Selected ASEAN Countries and the World Market
Source: Own Findings

3.2. Model Specification

3.2.1. NR Production Model

$$\boldsymbol{NRP_{it} = \beta_0 + \beta_1 NRPPrices_{it} + e_{it1}} \quad (1)$$

Where,

NRP_{it}	= NR production ('000 tonnes) in Thailand, Indonesia, Malaysia, Vietnam and Myanmar
$NRPPrices_{it}$	= NR price (USD/ton) in Thailand, Indonesia, Malaysia, Vietnam and Myanmar
β_0	= Intercept
β_1	= Regression coefficient/slope
e_{it1}	= Error term
it	= Panel data from 1997 to 2017 yearly of Thailand, Indonesia, Malaysia, Vietnam and Myanmar

3.2.2. NR Consumption Model

$$\boldsymbol{NRC_{it} = \beta_2 + \beta_3 NRCPrices_{it} + \beta_4 stock_{it} + e_{it2}} \quad (2)$$

where,

NRC_{it}	= NR consumption ('000 tonnes) in China, India, USA and Japan
$\mathrm{NRCPrices_{it}}$	= NR price (USD/ton) in China, India, USA and Japan
$stock_{it}$	= NR domestic stock ('000 tonnes) in China, India, USA and Japan
β_2	= Intercept
β_3 and β_4	= Regression coefficient/slope
e_{it2}	= Error term
it	= Panel data from 1997 to 2017 yearly of China, India, USA and Japan

3.2.3. NR Price Model

$$\boldsymbol{Sicom_t = \beta_5 + \beta_6 nrwp_{t-1} + \beta_7 nrwc_{t-1} + \beta_8 exr_{t-1} + \beta_9 cop_{t-1} + e_{t3}} \quad (3)$$

Where,

$Sicom_t$	= NR world price TSR20 (USD/ton) deflated by the CPI
$nrwp_t$	= Natural rubber world production ('000 tonnes)
$nrwc_t$	= Natural rubber world consumption ('000 tonnes)
exr_{t-1}	= Real exchange rate (USD/SGD)
cop_{t-1}	= Crude oil price (USD/barrel)
β_5	= Intercept
$\beta_6 \dots \beta_9$	= Regression coefficient/slope
e_{t3}	= Error terms
t	= Monthly time series data from January 2008 to December 2017

3.3. Hypothesis Testing

3.3.1. NR Production Model

H_{o1}: There is no positive relationship between NR price and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

H_{A1}: There is a positive relationship between NR price and NR production in Thailand, Indonesia, Malaysia, Vietnam and Myanmar.

3.3.2. NR Consumption Model

H_{o2}: There is no negative relationship between NR price and NR consumption in China, India, Japan and USA.

H_{A2}: There is a negative relationship between NR price and NR consumption in China, India, Japan and USA.

H_{o3}: There is no negative relationship between NR stock and NR consumption in China, India, Japan and USA.

H_{A3}: There is a negative relationship between NR stock and NR consumption in China, India, Japan and USA.

3.3.3. NR Price Model

H_{o4}: There is no positive relationship between NR production and NR price in the world market.

H_{A4}: There is a positive relationship between NR production and NR price in the world market.

H_{o5}: There is no negative relationship between NR consumption and NR price in the world market.

H_{A5}: There is a negative relationship between NR consumption and NR price in the world market.

H_{o6}: There is no negative relationship between real exchange rate and NR price in the world market.

H_{A6}: There is a negative relationship between real exchange rate and NR price in the world market.

H_{o7}: There is no positive relationship between crude oil price and NR price in the world market.

H_{A7}: There is a positive relationship between crude oil price and NR price in the world market.

3.4. Data Collection

In this study, secondary data was employed such as NR price, stock, production and consumption and was collected from several different sources such as GRM, IRSG and ANRPC. Other variables such as crude oil price and exchange rate were collected from World Bank and International Monetary Fund (IMF). Annual data from year 1997 to 2017 was collected for panel data analysis of model (1) and (2); while monthly data from January 2008 to December 2017 was also collected for time series econometrics for model (3).

3.5. Methodology

One of the research methodologies that was employed for the study was Panel Data analysis for the NR production and consumption models. Panel data is also known as longitudinal data which is the combination of cross-sectional data and time series data, and it is a study over time of a variable or group of subjects. There are three panel data models namely Pooled OLS (POLS), Fixed Effect Model (FEM) and Random Effect Model (REM). POLS will be preferred if the individual effect does not exist, as OLS can produce efficient and consistent parameters estimates. For the presence of individual effects, it can be either fixed or random effects. A FEM model examines if intercepts vary across groups or time periods, whereas a REM explores differences in error variance components across individuals or time periods. To determine which model would be suitable and appropriate for the study, Hausman Test by Hausman (1978) was employed to determine whether to select FEM or REM for the data analysis (Verbeek, 2008; Wooldridge, 2010).

Moreover, Vector Error Correction Method (VECM) analysis, Cointegration Rank Test and Granger Causality Test were employed to the NR world price model. A VECM is a restricted Vector Autoregressive (VAR) designed to those non-stationary time series that are co-integrated, and to determine the short-term dynamics between variables by restricting the behavior of variables in long run. It limits the long run relationship through their co-integrating relations, and error correction term denotes the deviation from long-run equilibrium. In a VECM model, it contains a cointegration equation as well as VECM equation. The former indicates the long run relationship between variables while the latter indicates the short run relationship between variables (Gujarati and Porter, 2009).

Cointegration tests examines whether the two variables are having long-run equilibrium relationship. Johansen maximum likelihood procedure was proposed by Johansen and Juselius (1990) was used to detect whether all the variables that were included in the system are co-integrated. Two types of cointegration tests were employed, namely the trace test and maximum Eigenvalue test. The maximum Eigenvalue statistics examined the null hypothesis that there were *r* co-integrating vectors against the alternative of *r+1* co-integrating vectors. On the other hand, trace statistics examined the null hypothesis of no co-integrating vector against the alternative of at least one co-integrating vector (Pindyck and Rubinfeld, 1998). Moreover, Granger Causality test was proposed by Granger (1969) and it is used to examine the causal relationship between two variables. This approach answered whether *x* caused *y* by how much of the current *y* could be explained by previous values of *x*. The results could be bi-directional, unidirectional or even no causality among variables (Gujarati and Porter, 2009).

4. RESULTS AND DISCUSSION

4.1. Panel Data Analysis

4.1.1. Panel Unit Root Tests

Table-1. Panel Unit Root tests results for NR production and consumption models

NR PRODUCTION MODEL

Variables	Levin, Lin and Chu			Fisher-PP		
	Level	Ln	1st diff	Level	Ln	1st diff
NRP	3.4507	-2.9742***	-6.6219***	1.3709	19.0755***	45.7664***
NRPPrices	-1.0616	-4.0846***	-8.5462***	9.0315	26.2706***	58.2563***

NR CONSUMPTION MODEL

Variables	Levin, Lin and Chu			Fisher-PP		
	Level	Ln	1st diff	Level	Ln	1st diff
NRC	0.0371	-1.6179*	-7.3599***	5.5479	10.0323	67.3440***
NRCPrices	-0.4108	-0.5060	-6.5162***	5.6983	3.6908	36.1577***
Stock	200.887	106.4100	-22.0186***	85.2247***	89.6391***	79.4204***

Source: Computed by the authors
Note: ***statistically significant at 0.01 level
*statistically significant at 0.10 level

H_0 = data is non-stationary (contains unit root)
H_A = data is stationary (no unit root)

Table 1 reveals the panel unit root tests results for both NR production and consumption models. Two unit root tests are employed, namely the Levin *et al.* (2002) test and Fisher-PP represents the Maddala and Wu (1999) unit root test. For NR production model, according to the test statistics from Levin *et al.* (2002) as well as Fisher-PP tests, results suggest that both variables, namely the NR production and NR price are non-stationary at level data. Instead, they are all stationary at Ln and first difference data which are statistically significant at α=0.01. Therefore, H_0 is rejected, there is no unit root (stationary) in the series.

For NR consumption model, test results of Levin *et al.* (2002) reveal that all the variables namely the NR consumption, NR price and stock are non-stationary at level data. Out of three variables, only NR consumption that is stationary at Ln data which is statistically significant at α=0.10. On the other hand, test results of Fisher-PP indicate that out of three variables, only stock that is stationary at level data and Ln data and is statistically significant at α=0.01 respectively. However, all the three variables are eventually stationary at first difference data under both panel unit root tests which is statistically significant at α=0.01. Therefore, H_0 is rejected and there is no unit root (stationary) in the series.

4.1.2. NR Production Model

4.1.2.1. Hausman Test

H_0 = REM is preferred
H_A = FEM is preferred

As mentioned in the previous section, Hausman test is carried out to select the appropriate model (either FEM or REM) for the data analysis. Result of Hausman test reveals that the p-value is **0.8726**, which is greater than α=0.05. Therefore, we do not reject H_0. Test result has suggested that REM is preferred for NR production model.

4.1.2.2. Random Effect Model (REM)

$$Ln\ NRP_{it} = 4.6145 + 0.4004\ Ln\ NRPrices_{it} + 0.1818\ e_{it}$$

(4)

t-stat: [12.8002***]

R^2 = 0.6472 Adj R^2 = 0.6437

Equation 4 shows the REM regression for NR production model. Ln model is employed for REM regression since both of the variables are stationary at Ln data at α=0.01 level (refer to table-1). In the NR production equation, it shows that R^2 equals to 0.6472, which means that 64.72 percent of the variation in the NR production model is well explained by the explanatory variable, namely the NR prices. It also indicates that there is a positive relationship between NR price and NR production in the five producing countries namely Thailand, Indonesia, Malaysia, Vietnam and Myanmar. Every one unit increase in NR price, on average, will have a positive effect on increasing the NR production by 0.4004 unit and it is statistically significant at α=0.01 level.

4.1.3. NR Consumption Model

4.1.3.1. Hausman Test

H_0 = REM is preferred

H_A = FEM is preferred

Hausman test is carried out again for this model to select either FEM or REM for data analysis. Result of Hausman test indicates that the p-value is **0.0017**, which is smaller than α=0.05. Therefore, we reject H_0. Test result has suggested that FEM is preferred for NR consumption model.

4.1.3.2. Fixed Effect Model (FEM)

$$\Delta\ NRC_{it} = 89.2309 - 0.0884\ \Delta\ NRPrices_{it} - 1.1739\ \Delta\ stock_{it} + 29.1167\ e_{it} \quad (5)$$

t-stat: [-2.2460**] [-1.2015]

R^2 = 0.3655 Adj R^2 = 0.3208

Equation 5 shows the FEM regression for NR consumption model. First difference model is employed for FEM regression since all the variables are stationary only at first difference data at α=0.01 level (refer to table-1). In the NR consumption equation, the R^2 equals to 0.3655, which means that 36.55 percent of the variation in the NR consumption model is well explained by the explanatory variables, namely the NR prices and stock. Equation 5 shows that NR price is the most important variable in the model. It also indicates that there is a negative relationship between NR price and NR consumption in the four consuming countries namely China, India, Japan and USA. Every one unit increase in NR price, on average, will have a negative effect on decreasing the NR consumption by 0.0884 unit, holding other variable constant, and it is statistically significant at α=0.05 level. However, results show that there is a negative insignificant relationship between NR stock and NR consumption.

4.2. Time Series Data Analysis

4.2.1. Unit Root Tests

Table-2. Unit Root tests results for NR Price models

Variables	Augmented Dickey Fuller (ADF)			Phillips Perron (PP)		
	Level	Ln	1st diff	Level	Ln	1st diff
SICOM	-1.6058	-1.5598	-7.5924***	-1.4472	-1.4511	-7.6789***
nrwp	-1.0219	-1.4483	-9.7166***	-2.1234	-2.1063	-11.6524***
nrwc	-2.7359*	-3.1371**	-4.4253***	-3.6192***	-3.4689**	-26.2765***
EXR	-0.5977	-0.5555	-9.0955***	-0.6999	-0.5555	-9.0987***
COP	-1.7846	-1.7667	-8.4864***	-2.1419	-2.0208	-8.4840***

Source: Computed by the authors
Note: ***statistically significant at 0.01 level
**statistically significant at 0.05 level
*statistically significant at 0.10 level

H_0 = data is non-stationary (contains unit root)

H_A = data is stationary (no unit root)

Table 2 reveals the unit root tests results for NR price model. Two unit root tests are employed, namely the Augmented Dickey Fuller (ADF) test developed by Dickey and Fuller (1981) and Phillip Perron (PP) test developed by Phillips and Perron (1988). Both of the test results show that only NR consumption is stationary at level and Ln data. For ADF test, NR consumption is stationary at level and Ln data at α=0.10 and 0.05 respectively; while for PP test, it is stationary at level and Ln data at α=0.01 and 0.05 respectively. All other variables are non-stationary in both level and Ln data. Instead, all the five variables are stationary at first difference data in both ADF and PP tests at α=0.01 level. Therefore, we reject the null hypothesis, the data is stationary at first difference data.

4.2.2. Cointegration Equation

$$-0.0160\,\Delta\, SICOM_t + 0.0099\,\Delta\, nrwp_t - 0.0670\,\Delta\, nrwc_t - 0.000002\,\Delta\, exr_t + 0.00003\,\Delta\, cop_t = 0 \quad (6)$$

t-stat: [-1.3234*] [2.0434**] [-11.5369***] [-2.1117**] [0.0776]

Equation 6 illustrates the cointegration equation of NR price which is from the VECM model. In the NR price SICOM model, it shows that 4 variables namely the NR price SICOM, NR production, real exchange rate and NR consumption are the important variables. NR production and SICOM are having a positive long run cointegrated relationship which is statistically significant at α=0.05 level; while real exchange rate and NR consumption are having a negative long run cointegrated relationship with SICOM which are statistically significant at α=0.05 and 0.01 level respectively. Test statistic suggests that there is no long run cointegrated relationship between crude oil price and SICOM.

4.2.3. VECM Equation

$$\Delta\, SICOM_t = 0.0845 + 0.2224\,\Delta\, nrwp_{t-1} - 0.1496\,\Delta\, nrwc_{t-1} - 1485.124\,\Delta\, exr_{t-1} + 0.1527\,\Delta\, cop_{t-1}$$

t-stat: [0.9531] [-0.7886] [-1.2054] [0.0625]

$$+0.3974\,\Delta\, SICOM_{t-1} + 22.7688 e_t \quad (7)$$

[4.3899***]

R^2 = 0.2080 Adj R^2 = 0.1648

Equation 7 indicates the VECM equation of NR price SICOM model. It shows that the R^2 equals to 0.2080 which means that 20.80 percent of the short-term variation in the SICOM VECM equation is well explained by the explanatory variables. As shown in equation 7, the previous value of SICOM is the most important variable in the model which is statistically significant at α=0.01 level. Therefore, every one unit increase in the previous value of SICOM, on average, will have a positive effect on increasing SICOM by 0.3974 unit, holding other variables constant.

4.2.4. Cointegration Rank Test

Table-3. Results of Johansen Cointegration Test (Trace)

Hypothesized No. of Cointegrating Equation(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.624653	300.3936	69.81889	0.0001
At most 1 *	0.423251	185.7447	47.85613	0.0000
At most 2 *	0.359531	121.3540	29.79707	0.0000
At most 3 *	0.311930	69.22415	15.49471	0.0000
At most 4 *	0.195709	25.48196	3.841466	0.0000

Source: Computed by the authors
Trace test indicates 5 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon *et al.* (1999) p-values

Table-4. Results of Johansen Cointegration Test (Maximum Eigenvalue)

Hypothesized No. of Cointegrating Equation(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.624653	114.6489	33.87687	0.0000
At most 1 *	0.423251	64.39071	27.58434	0.0000
At most 2 *	0.359531	52.12982	21.13162	0.0000
At most 3 *	0.311930	43.74219	14.26460	0.0000
At most 4 *	0.195709	25.48196	3.841466	0.0000

Source: Computed by the authors
Max-eigenvalue test indicates 5 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon *et al.* (1999) p-values

H_0 = there is no cointegration

H_A = there is cointegration

Both of the tables above show the results of Johansen Cointegration Test. Table 3 reveals the Trace test results while table 4 reveals the Maximum Eigenvalue test results. Test statistics from both Trace and Maximum Eigenvalue tests indicate that six cointegrating equations are statistically significant at α=0.01 level, which means that long-term equilibrium relationship between variables are met. Therefore, null hypothesis is rejected, there is cointegration existing between variables.

4.2.5. Granger Causality Test

Table-5. Results of Granger Causality test

Dependent Variable	Sig-p value				
	SICOM	nrwp	nrwc	exr	cop
SICOM	-	0.3187	0.0952*	0.0073***	0.6040
nrwp	0.8204	-	0.0004***	0.1753	0.0006***
nrwc	0.8560	0.0048***	-	0.3021	0.0045***
exr	0.5490	0.1130	0.0359**	-	0.1726
cop	0.0810*	0.6264	0.4281	0.2418	-

Source: Computed by the authors
Note: ***statistically significant at 0.01 level
**statistically significant at 0.05 level
*statistically significant at 0.10 level

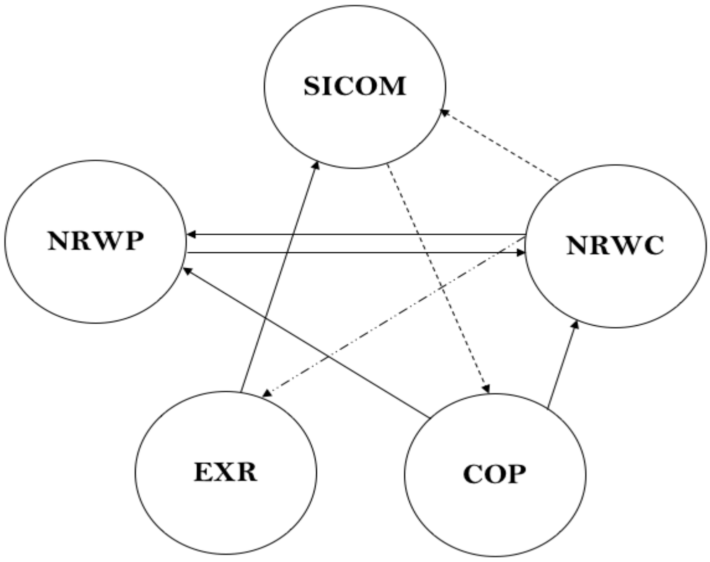

Figure-6. Granger Causality test results

Source: Computed by the authors
Note: ——— statistically significant at 0.01 level
— · · — · · statistically significant at 0.05 level
- - - - - - - statistically significant at 0.10 level

Table 5 shows the test results of Granger Causality test while figure 6 illustrates the directions of causality relationships between variables of SICOM NR price model. Test statistics suggest that there is unidirectional causality relationship running from (1) NR consumption to SICOM at α=0.10 level; (2) SICOM to crude oil price at α=0.10 level; (3) NR consumption to real exchange rate at α=0.05 level; (4) real exchange rate to SICOM at α=0.01 level; (5) crude oil price to NR consumption at α=0.01 level; and (6) crude oil price to NR production at α=0.01 level. On the other hand, there is only one bi-directional causality relationship between NR production and NR consumption which is statistically significant at α=0.01 level.

5. CONCLUSION

This study aimed to develop and analyze the production, consumption and price models of the NR in selected ASEAN countries and world market. NR production and consumption model were analyzed by panel data analysis, using annual data from year 1997 to 2017; while NR price model was studied by using time series econometrics analysis such as VECM and cointegration equation, cointegration rank test as well as Granger Causality test by using monthly data from January 2008 to December 2017. Results suggested that NR production and NR price are positively related and having a long run cointegrated relationship. This can be supported by the research done by Kannan (2013); Karunakaran (2017); Arunwarakorn *et al.* (2017) and Van Asselt *et al.* (2017). This could be explained as when the rubber price increases, farmers will be encouraged to produce more rubber and supply more to the market, which leads to an increase in production of NR. Volatility of the NR price affected its production, and indirectly would influence farmers and smallholders' livelihood. Therefore, an increase of rubber price would lead to increase in rubber production, which would induce higher smallholders' income and a better living standard.

Besides, results of the study also found out that NR price and NR consumption are negatively related and they are having a long run cointegrated relationship too. This finding could be supported by the study of Khin *et al.* (2011); Khin and Thambiah (2015) and Arunwarakorn *et al.* (2017). This could be explained as when the NR price rises, consumers will now consume less NR, since they can switch their preferences to the substitute products which is SR, thus consumption of NR will drop. Another finding was that the real exchange rate and NR price are negatively related, and they are having a long run cointegrated relationship (Khin *et al.* (2016). When the currency appreciates, the product will become more expensive which will then drive down the consumption. When the world demand starts to drop, the NR price will then be affected to drop as well. Moreover, Zhang and Qu (2015); MdLudin *et al.* (2016) and Khin *et al.* (2017) found out that NR price and crude oil price are positively related, and proved that crude oil price is cointegrated with NR price. Since crude oil itself is one of the main raw materials for the SR production, therefore increases in crude oil price will drive up SR price, which the NR will become cheaper now and will stimulate the demand and production in NR. However, the finding of this study indicated that, in cointegration and VECM equations, there are no long run and short run relationship found between crude oil price and NR price. They are positively related but statistically insignificant. This could be due to the different sampling period with the previous researches.

In a nutshell, NR is one of the important commodities in the world and has been playing a vital role especially in producing countries, acting as the economic development contributor. However, the fluctuation and instability of NR price have been an issue that researchers are eager to investigate the factors behind. Undeniably, the fundamental factors that are affecting the NR price are its supply-demand trend, and it has upside and downside factors for both supply and demand side as well. For supply side, there are downside risk factors such as the possibility of unfavorable climate changes (drought or unseasonal rain) in producing countries which will severely affect the NR production. This phenomenon can be seen back in 2011 when producing countries such as Thailand, Indonesia and Malaysia suffered from heavy rain and had led to low yields of rubber production, and eventually driven up rubber price dramatically. Upside risk factors for supply side is that there is a possible jump in NR price in 2017-18 which is caused by the potential surge in crude oil price as well as a boom in commodity prices.

On the other hand, for demand side, the downside risk factors include the uncertainty of the world economy. There are possibilities that the global economy is not growing up at the expected rate, or it actually grows faster than anticipated. A possibility of an introduction of new policies which is related to the use of vehicles or tires in some particular countries will also affect the demand for world NR. Upside risk factor for demand side will be the surge in crude oil price. As discussed, increase in crude oil price will drive the SR price up, and the demand for NR will then be stimulated. Furthermore, one of the critical factors is the currency movement in the world. It is also proved that exchange rate and NR price are related. As NR is internationally traded in terms of US dollar, thus any movement in own countries currency against US dollar will definitely have an impact on the NR price. The exchange rate itself also derives the competitiveness of producing and exporting countries. When a currency devalues against US dollar, it will prompt exporters to reduce NR price to attract buyers. When more and more exporters adopt the same strategy, NR price is then expected to drop in terms of US dollar. Therefore, a depreciating currency is expected to depress rubber price in terms of US dollar.

However, NR price is not solely affected by the world supply-demand trends. In fact, NR price is driven largely by non-fundamental factors other than its supply and demand. It is known that crude oil price is a crucial factor of NR price. Speculative investors in rubber futures consider that SR is the substitute of NR. Since SR is petroleum-derived, their input cost will definitely depend on crude oil price. Therefore, when there are any changes in the world crude oil price, speculative investors bet on possible substitution between NR and SR. So, when crude oil price rises, investors will tend to invest in NR in future, and conversely, they will invest in SR futures if the crude oil price appears to be decreasing. The NR market generally tracks the directional trends in the crude oil market to expect any possible swing in the market.

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